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| Team nr: |  |
| Students: |  |

Final report  
model for grass and water

## General guidelines

Remove this section when you are finished with your report.

Be concise. Use wisely the space to focus on the analysis of results.

Tables and figures must be self-explanatory. Use detailed captions.

* Tables: include units, and round values to an adequate significant digit.
* Figures: label axes, and include units. Text and numbers must be readable.

Analysis of results is more than a simple description of the graphs (e.g., A is larger than B):

* Explain the possible causes of the observed behaviour.
* Reflect on the impact of your assumptions on simulation results.

Add your list of references at the end of this report, and make sure you refer to them in the text when necessary.

**Maximum 12 pages** (excluding References and Appendices)

## Python files

grass\_sol.py place it in folder MBPS/mbps/models

water\_sol.py place it in folder MBPS/mbps/models

grasswater\_eval.py place it in folder MBPS/mbps

grasswater\_sa.py place it in folder MBPS/mbps

# Research question

Briefly describe the objective of the model, oriented towards the improvement of yearly grass yield.

Write a clear, complex, quantifiable question.

Add also two or three sub-questions, based on your findings from this case.

Detailed [guidelines](https://writingcenter.gmu.edu/guides/how-to-write-a-research-question).

**Suggested: 1/2 page**

# Gather information

List and explain relevant data and sources used.

Include tables and figures only when they contribute to the explanation (e.g., weather data or grass growth data, use to explain expected or simulated grass growth).

Mention any limitations in the data and, if necessary, include implications from these limitations in your assumptions in the next step.

**Suggested. 1 page**

# System Dynamics Modelling

Add your own updated Forrester diagrams.

Place the lists of equations in an appendix. Remember to refer to that appendix in this section.

In the appendix, highlight the changes made to the model equations and parameter values with respect to the original information from the papers.

List the main assumptions used for the models. Focus on the assumptions that you analyse through this case, and that may have an impact on your simulation results.

Briefly explain your harvest and irrigation strategy (and include its elements in your Forrester diagram). Only implement your strategy in the last section of this report (answer to research question) unless otherwise indicated.

**Suggested. 2 ½ pages**

# Model evaluation

Evaluate the model in two cases (e.g., two years, or two locations).

Analyse the differences between the cases and reflect on the possible impact of assumptions.

## Challenge

Simulate the models using a time step of 1 hr. Make sure you use the corresponding disturbances (weather) data, and necessary interpolations.

Determine whether the more detailed dynamics have a significant impact on the simulation results.

**Suggested: 1 page**

# Sensitivity analysis

Perform a OAT sensitivity analysis based on your team’s choice of reference parameter values.

Show the results of the three parameters with the highest impact (normalized sensitivities). Explain your criterion.

Reflect on the limitations of the OAT method.

## Challenge

Use 3 different reference parameter combinations.

Compute the overall normalized sensitivities (e.g., average of normalized sensitivities).

Explain your criterion to identify the most relevant parameters.

You may include additional plots of this challenge in the appendix.

**Suggested: 2 pages**

# Model calibration

Calibrate the model for 2 or 3 parameters. Estimate your relevant parameters with least-squares minimization, using data from NL for grass growth and the corresponding weather.

If the first calibration results are unreliable, select a second combination of parameters. For example, removing parameters with high relative error, or high correlation, and adding other relevant parameters.

If the second calibration is also unreliable, repeat the process a third time (and stop the process there). Report the results for the calibration accuracy of each step.

Report the simulated model prediction and parameters accuracy for the final calibration.

Discuss possible limitations from your calibration results.

## Challenge

If, after the first 3 attempts at calibration, you still obtain unreliable parameter estimates, continue until you obtain satisfying results. This process requires some trial and error (you may notice that the correlation between two specific parameters changes depending on the choice of a third parameter).

Report accuracy results from only 3 steps of your process, including the final results. You may add a table of all attempts in the appendix.

**Suggested: 2 pages**

# Model verification

Verify or validate the calibrated model against a second data set of grass growth (e.g., a second location in the Netherlands or Norway timothy grass).

If the model cannot predict accurately the second data set, discuss possible causes and possible impact of your assumptions.

## Challenge

Implement harvest in your simulation and verify whether the model can accurately predict the measured growth (cumulative or final yield). Discuss your results.

**Suggested: 1 page**

# Uncertainty analysis

Compute the uncertainty propagation using Monte Carlo simulations from your estimated parameters. Identify the parameter estimate with the highest impact on the model prediction uncertainty.

## Challenge

Implement weather uncertainty to simulate general grass growth in the Netherlands.

Describe and explain how you implement random variation on the weather disturbances, and identify which weather disturbance has the highest impact on the model prediction uncertainty.

**Suggested: 1 page**

# Answer the research question

Determine a model-based harvest strategy (including uncertainty). For example: harvest whenever , irrigate when dry and hot weather occur. Test and improve your harvest strategy to find a possible improvement on the average yield in the Netherlands (1.0-1.3 kgDM m-2).

Report the results of your final harvest strategy. Answer your research question. Reflect and discuss possible limitations and impact of assumptions on your answer.

## Challenge

Include prediction uncertainty in your harvest strategy. Include the analysis of uncertainty in the answer to your research question.

**Suggested: 1 page**

# References

List your references here. Use APA style referencing format.

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# Appendix

Add any necessary appendices.

This content does not count on the page limit and will not be evaluated.

**NOTE:** Excessive appendices may result in deduction of points.