





growR: R Implementation of the Vegetation Model ModVege

Kevin P. Kramer ^{1*} and Pierluigi Calanca ^{1*}

¹ Agroscope, Climate and Agriculture Group, Reckenholzstrasse 191, CH-8046 Zürich, Switzerland 
Corresponding author * These authors contributed equally.

DOI: [10.21105/joss.06260](https://doi.org/10.21105/joss.06260)

Software

- [Review](#) 
- [Repository](#) 
- [Archive](#) 

Editor: [Michael Mahoney](#) 

Reviewers:

- [@shubhamjain15](#)
- [@RobLBaker](#)

Submitted: 15 December 2023

Published: 14 February 2024

License

Authors of papers retain copyright and release the work under a Creative Commons Attribution 4.0 International License ([CC BY 4.0](#)).

Summary and Statement of Need

Grasslands constitute one of Earth's most widespread terrestrial ecosystems ([Zhao et al., 2020](#)) and managed grasslands are a core element in global agriculture, providing roughly half the feed inputs for global livestock systems ([Herrero et al., 2013](#)). Beside their contribution to global food production, they provide a catalogue of other ecosystem services, such as water flow and erosion regulation, pollination service, carbon sequestration and climate regulation ([Zhao et al., 2020](#)). The latter have become particularly important in light of anthropogenic climate change ([Bezner Kerr et al., 2022](#)).

There is thus ample motivation to study the properties and dynamics of grasslands. Mathematical models are widely used to assess climate change impacts on grassland functioning. Additionally, such models can be employed in agricultural and political decision support, see e.g. [GrazPlan](#) ([Moore et al., 1997](#)). Dozens of models have been formulated and tested in recent decades. Each of these models has been created with different applications in mind and thus comes with its own focal points and a set of advantages and disadvantages. To give just a few examples:

- The [Hurley Pasture Model](#) ([Thornley, 1998](#)) is a detailed mechanistic model for managed pastures.
- [BASGRA](#) ([Van Oijen et al., 2015](#)) and its descendant [BASGRA_N](#) ([Höglind et al., 2020](#)) are multi-year grassland models which include tiller dynamics.
- [PROGRASS](#) ([Lazzarotto et al., 2009](#)) was developed to capture the interactions in grass/clover mixtures.
- The focus of [PaSim](#) ([Graux et al., 2011](#)) is the investigation of livestock production under climate change conditions.
- [ModVege](#) ([Jouven et al., 2006](#)) is a mechanistic model that is designed to capture the dominant processes with a minimum of required input parameters.
- The [Moorepark St Gilles](#) ([Ruelle et al., 2018](#)) and [Gras-sim](#) ([Kokah et al., 2023](#)) models both extend [ModVege](#) in terms of soil water and nitrogen dynamics and management.

The existing grassland models vary not only in their formulation and structural complexity, but also in the manner in which they are implemented and distributed, ranging from sets of zipped script files being shared bilaterally among researchers to professionally developed and maintained (open or closed) software suites. With this large variability in implemented models, version control, transparency and clear traceability of employed model implementations becomes challenging, which is detrimental for the reproduction of scientific results.

This paper describes the software package [growR](#). [growR](#) is an implementation of the vegetation model [ModVege](#) ([Jouven et al., 2006](#)) in the R language ([R Core Team, 2021](#)). It is packaged and distributed via the [comprehensive R archive network \(CRAN\)](#) with the [source code freely and openly available](#) and thus presents a contribution to the above formulated need for

reproducible practices in ecosystems modelling.

Package Description

The origin of growR lies in an existing, unpublished R implementation of the same vegetation model. This original code base has been used to simulate grass growth dynamics and the effects of drought in Switzerland (Calanca et al., 2016). It has since been refactored into an R package which is currently being used to investigate the impacts of climate change on Swiss agriculture in the framework of the National Center for Climate Services' Impacts program.

The growR package contains classes which define data structures and functionalities for parsing the model inputs, carrying out the grass growth simulations and providing different forms of output. These classes and their functionalities are wrapped in high level functions which streamline the most common use cases. In addition to this core functionality, the package contains utilities for some common tasks that arise in ecosystem modelling (and beyond), like setting up a clean directory structure, assessing model performance when compared to a set of validation data and carrying out sweeps over parameter space in order to aid model calibration.

Model Extensions

The core model implementation follows the description by Jouven et al. (2006) but it contains a number of extensions that have proven valuable. Use of any of these additions is optional, so the user is free to work with the model in its original formulation or with any combination of the provided extensions. These additions include:

- Simulation of snow cover by use of a model by Kokkonen et al. (2006) and Rango & Martinec (1995), important when modelling grassland in mountainous regions.
- A cut decision algorithm, which allows the model to simulate management decisions in the absence of such input data. The decision process is based on work by Huguenin-Elie et al. (2017) and Petersen et al. (2021).
- Plant responses to elevated CO₂ conditions: The evapotranspiration (Kruijt et al., 2008) and photosynthetic rates (Kellner et al., 2017; Soltani & Sinclair, 2012) of plants can be modified by the atmospheric CO₂ concentration.
- Use of the multicriterial thermal definition of the growing season, as proposed by Schaumberger (2011).
- All model parameters default to the values provided by Jouven et al. (2006), but are accessible to adjustments by the user.

Publications discussing and validating these extensions are in preparation.

Conclusion

The growR package enhances the grassland modelling landscape with a model implementation complete with analysis tools and utilities. The distribution as an R package on CRAN ensures an easy installation procedure and a relatively high standard of code quality and documentation through CRAN's submission policies.

Acknowledgements

The work of K.P.K. has been supported by Agroscope, the National Center for Climate Services and the Federal Office for Agriculture.

References

- Bezner Kerr, R., Hasegawa, T., Lasco, R., Bhatt, I., Deryng, D., Farrell, A., Gurney-Smith, H., Ju, H., Lluch-Cota, S., Meza, F., Nelson, G., Neufeldt, H., & Thornton, P. (2022). Food, fibre, and other ecosystem products [Book Section]. In H. O. Pörtner, D. C. Roberts, M. Tignor, E. S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, & B. Rama (Eds.), *Climate change 2022: Impacts, adaptation and vulnerability. Contribution of working group II to the sixth assessment report of the intergovernmental panel on climate change* (pp. 713–906). Cambridge University Press. <https://doi.org/10.1017/9781009325844.007>
- Calanca, P., Deléglise, C., Martin, R., Carrère, P., & Mosimann, E. (2016). Testing the ability of a simple grassland model to simulate the seasonal effects of drought on herbage growth. *Field Crops Research*, 187, 12–23. <https://doi.org/10.1016/j.fcr.2015.12.008>
- Graux, A.-I., Gaurut, M., Agabriel, J., Baumont, R., Delagarde, R., Delaby, L., & Soussana, J.-F. (2011). Development of the Pasture Simulation Model for assessing livestock production under climate change. *Agriculture, Ecosystems & Environment*, 144(1), 69–91. <https://doi.org/10.1016/j.agee.2011.07.001>
- Herrero, M., Havlík, P., Valin, H., Notenbaert, A., Rufino, M. C., Thornton, P. K., Blümmel, M., Weiss, F., Grace, D., & Obersteiner, M. (2013). Biomass use, production, feed efficiencies, and greenhouse gas emissions from global livestock systems. *Proceedings of the National Academy of Sciences*, 110(52), 20888–20893. <https://doi.org/10.1073/pnas.1308149110>
- Höglind, M., Cameron, D., Persson, T., Huang, X., & van Oijen, M. (2020). BASGRA_N: A model for grassland productivity, quality and greenhouse gas balance. *Ecological Modelling*, 417, 108925. <https://doi.org/10.1016/j.ecolmodel.2019.108925>
- Huguenin-Elie, O., Mosimann, E., Schlegel, P., Lüscher, A., Kessler, W., & Jeangros, B. (2017). *Grundlagen für die Düngung landwirtschaftlicher Kulturen in der Schweiz (GRUD)*. 9, 1–22.
- Jouven, M., Carrère, P., & Baumont, R. (2006). Model predicting dynamics of biomass, structure and digestibility of herbage in managed permanent pastures. 1. Model description. *Grass and Forage Science*, 61(2), 112–124. <https://doi.org/10.1111/j.1365-2494.2006.00515.x>
- Kellner, J., Multsch, S., Houska, T., Kraft, P., Müller, C., & Breuer, L. (2017). A coupled hydrological-plant growth model for simulating the effect of elevated CO₂ on a temperate grassland. *Agricultural and Forest Meteorology*, 246, 42–50. <https://doi.org/10.1016/j.agrformet.2017.05.017>
- Kokah, E. U., Knoden, D., Lambert, R., Himdi, H., Dumont, B., & Bindelle, J. (2023). Modeling the daily dynamics of grass growth of several species according to their functional type, based on soil water and nitrogen dynamics: Gras-sim model definition, parametrization and evaluation. *Journal of Agriculture and Food Research*, 100875. <https://doi.org/10.1016/j.jafr.2023.100875>
- Kokkonen, T., Koivusalo, H., Jakeman, A., & Norton, J. (2006). Construction of a degree-day snow model in the light of the ten iterative steps in model development. *iEMSs Third Biennial Meeting: "Summit on Environmental Modelling and Software"*. International Environmental Modelling and Software Society, Burlington, USA, July 2006.
- Kruijt, B., Witte, J.-P. M., Jacobs, C. M. J., & Kroon, T. (2008). Effects of rising atmospheric CO₂ on evapotranspiration and soil moisture: A practical approach for the Netherlands. *Journal of Hydrology*, 349(3), 257–267. <https://doi.org/10.1016/j.jhydrol.2007.10.052>
- Lazzarotto, P., Calanca, P., & Fuhrer, J. (2009). Dynamics of grass–clover mixtures—An analysis of the response to management with the PROductive GRASsland Simulator (PRO-

- GRASS). *Ecological Modelling*, 220(5), 703–724. <https://doi.org/10.1016/j.ecolmodel.2008.11.023>
- Moore, A. D., Donnelly, J. R., & Freer, M. (1997). GRAZPLAN: Decision support systems for Australian grazing enterprises. III. Pasture growth and soil moisture submodels, and the GrassGro DSS. *Agricultural Systems*, 55(4), 535–582. [https://doi.org/10.1016/S0308-521X\(97\)00023-1](https://doi.org/10.1016/S0308-521X(97)00023-1)
- Petersen, K., Kraus, D., Calanca, P., Semenov, M. A., Butterbach-Bahl, K., & Kiese, R. (2021). Dynamic simulation of management events for assessing impacts of climate change on pre-alpine grassland productivity. *European Journal of Agronomy*, 128, 126306. <https://doi.org/10.1016/j.eja.2021.126306>
- R Core Team. (2021). *R: A Language Environment for Statistical Computing*. R Foundation for Statistical Computing. <https://www.R-project.org/>
- Rango, A., & Martinec, J. (1995). Revisiting the Degree-Day Method for Snowmelt Computations. *JAWRA Journal of the American Water Resources Association*, 31(4), 657–669. <https://doi.org/10.1111/j.1752-1688.1995.tb03392.x>
- Ruelle, E., Hennessy, D., & Delaby, L. (2018). Development of the Moorepark St Gilles grass growth model (MoSt GG model): A predictive model for grass growth for pasture based systems. *European Journal of Agronomy*, 99, 80–91. <https://doi.org/10.1016/j.eja.2018.06.010>
- Schaumberger, A. (2011). *Räumliche Modelle zur Vegetations- und Ertragsdynamik im Wirtschaftsgrünland* [PhD thesis]. Technische Universität Graz.
- Soltani, A., & Sinclair, T. R. (2012). *Modeling Physiology of Crop Development, Growth and Yield*. CABI. ISBN: 978-1-84593-971-7
- Thornley, J. H. M. (1998). *Grassland Dynamics: An Ecosystem Simulation Model*. CAB International. ISBN: 978-0-85199-227-3
- Van Oijen, M., Höglind, M., Cameron, D. R., & Thorsen, S. M. (2015). *BASGRA_2014*. Zenodo. <https://doi.org/10.5281/zenodo.27867>
- Zhao, Y., Liu, Z., & Wu, J. (2020). Grassland ecosystem services: A systematic review of research advances and future directions. *Landscape Ecology*, 35(4), 793–814. <https://doi.org/10.1007/s10980-020-00980-3>